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Identification of Suitable Areas for Solid Waste Management with the help of Remote Sensing and GIS technology- A case study of Ludhiana, Punjab.

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Abstract - **Solid waste not only spoils the landscape but is also one of the major contributors in the deteriorating environment especially in the urban areas of India. Solid waste can be converted into a useful resource if it is managed carefully and at an appropriate area. In this process the foremost important step in solid waste management is the careful and precise identification of suitable area. This study attempts to identify suitable areas for solid waste management for Ludhiana city. It is an industrial city of Punjab situated on the banks of river Sutlej. The suitable areas are identified with the help of Remote Sensing and Geographic Information System. A variety of factors are considered like landuse landcover, groundwater, soil drainage, distance from settlements, distance from canal, distance from drains, slope, distance from city, distance from roads etc. Buffers are made for several factors to categorize the study area. Shape files of all these factors are converted into rasters so that weighted overlay analysis can be applied in ArcMap. All factors are assigned percentage of importance and the subclasses of factors are assigned scale values. The newly generated raster classifies the study area in various suitability zones alongwith suitability index. The most suitable area is converted into KML file and verified on Google Earth. Such scientific identification of area for solid waste management can help in mitigating the environmental pollution.**

keywords - **Remote Sensing, GIS, Raster, buffers, weighted overlay analysis.**

I. Introduction

Ludhiana is the most populated and largest city of Punjab covering an area of 159.37 sq. km. and supporting 16,18,879 people with decadal growth rate (2001-2011) of 33.79% (Census of India, 2011). It is the first metropolitan city of Punjab. Ludhiana is an industrial city having woolen, leather, machine tools, bike, motorbike and many more industries. However it is recognized for its hosiery industry. BBC calls it 'Manchester of India' and World Bank has once ranked it as the best Indian city to do business. It lies roughly in the middle of Punjab state on the left bank of river Sutlej. The city is well connected with road, rail and air links.

II. Current Status

The task of collection and disposal of solid waste is assigned to the public health department of Ludhiana municipal corporation. The Municipal Corporation of Ludhiana was formed in 1977 and today it is the biggest municipal corporation of Punjab. A vast infrastructure has been created by the municipal corporation for the solid waste management yet it is in poor state because of limited and poorly maintained solid waste collection points. Transportation of solid waste from collection points to the dumping sites is not properly managed. 3662 workers and a fleet of 68 vehicles are involved in the solid waste management. Facility of collection of garbage extends to the entire area that falls under Ludhiana municipal corporation. Everyday 850 metric tons of solid waste is generated in Ludhiana municipal corporation. Per capita waste generation is 535 gms which is a little higher than other cities of the state/country (Master Plan Report, Ludhiana, 2011). More than half of solid waste is generated by the residential and open areas followed by 1/4 by commercial areas and 1/5 by industrial areas.

Solid waste management involves several stages like collection of waste and then its transportation to the collection centers numbering 269 and lastly its transportation to the dumping sites for final disposal. At present three sites are being used for solid waste dumping : Jamalpur (25 acres), Jainpur (10 acres) and Noorpur bet (21 acres). The site of Jainpur has reached its saturation limit and corporation has closed it but still it is being used because of its nearness to the city. Land at Noorpur Bet is specifically purchased to install solid waste treatment plant. All these sites are not lined hence several environmental risks are posed like soil pollution, groundwater contamination, air pollution, health risks to the people and animals. The biomedical waste is handled by M/s Ramky Enviro Engineers Ltd. at a treatment plant at Jamalpur. A total of 5 tons of biomedical waste can be disposed of per day which is enough to cater all the hospitals and medical colleges of the state. The site of Jamalpur is most extensively used for solid waste dumping. Here the task of solid waste management has been awarded to A2Z Infrastructure ltd (Master Plan Report, Ludhiana, 2011).

III. Study Area

The study area of Ludhiana municipal corporation is not limited to the municipal limit but extends beyond that to include the outgrowths. In the revised rules (2016) of solid waste management it is clearly mentioned that these rules shall also apply to the urban agglomerations. For the city of Ludhiana a buffer of 10 km is made around the city to define the study area. Hence the study area begins from the outer limit of city to a distance of 10 km in all directions. Further, the study area is clipped by the

Ludhiana district boundary so that it doesn't enter into the neighbouring districts. That's why in the north the study area doesn't extend to the maximum distance of 10 km because that area falls in adjoining Jalandhar district. After clipping, the study area covers an area of 865 sq km with perimeter of 130 km.

IV. Factors

Selection of factors is a crucial step in site identification process. For similar study of Kottayam, Kerala (Nishanth T. and others) factors of lithology, geomorphology, slope, drainage, population, distance from roads, distance from streams and distance from drainage are considered. In another study of Hosur, Tamil Nadu (S. Sunder Rajan and others) factors of Slope, drainage, water bodies, residential areas, population, distance to roads, distance to drainage, distance to water bodies and distance to residential areas are analyzed. In the present study a total of 9 factors are being considered to identify suitable site for solid waste management of Ludhiana municipal corporation. These are landuse landcover, groundwater level, soil drainage, distance from city, distance from drains, distance from canals, distance from villages, slope and distance from roads. All features are digitized satellite imageries and brought into GIS environment as feature datasets.

V. Material and Methodology

S. no.	FACTORS	PERCENTAGE OF INFLUENCE	SUBCLASSES	SCALE VALUE (0-5)
1	Landcover	22	Cultivated	5
			Industry	3
			Plantation	2
			Villages	0
2	Soil Drainage	18	D4 (moderately well drained)	5
			D5 (well drained)	4
			D7 (excessively drained)	2
3	Groundwater	12	5-10 m	3
			10-20 m	4
			20-30 m	5
4	City Multi Buffers	12	0-2 km	1
			2-4 km	2
			4-6 km	3
			6-8 km	4
			8-10 km	5
5	Canal Buffers	10	0 - 250 m	1
			250-500 m	2
			500-750 m	3
			750-1000 m	4
			> 1000 m	5
6	Drain Buffers	8	0 - 250 m	1
			250-500 m	2
			500-750 m	3
			750-1000 m	4
			> 1000 m	5
7	Village Buffer	8	0 - 500 m	1
			> 500 m	5
8	Slope	7	0-5 degree	5
			5-10 degree	4
			10-15 degree	3
			15-20 degree	2
			>20 degree	1
9	Road Buffer	3	0-100 m	5
			100-200 m	4
			200-300 m	3
			300-400 m	2
			> 400 m	1

Table 1: Assigning percentage of influence to factors and weights to the subclasses of factors

All the nine factors discussed above are first of all digitized. Each factor is drawn as a feature dataset in a separate layer. Each feature dataset is saved as a shape file. Layers of features are made by merging several feature datasets e.g. Landuse Landcover layer is made by merging feature datasets of settlement, plantation, industry and cultivated land. Once landuse landcover layer is complete, it is converted into raster dataset. Second factor is of soil drainage which refers to the movement of water in soil. The soil drainage layer is digitized by georeferencing the soil map of Punjab. This map is prepared jointly by National Bureau of Soil Survey and Landuse Planning, Department of Soil and Water conservation of Punjab, Punjab Agriculture University, Ludhiana. Later this map was revised by the Punjab Remote Sensing Centre, Ludhiana. This map is available on www.*punenvis.nic.in*. On the basis of soil drainage there are seven types of soil in Punjab but in this study area there are only three kinds of soils i.e. D4 (moderately well drained), D5 (well drained) and D7 (excessively drained). After digitizing the soil drainage it is also converted into raster dataset. Next, groundwater data is also digitized by georeferencing the groundwater district map prepared by central groundwater board, ministry of water resources, Govt. of India. This map is available at *http://cgwb.gov.in/District-GW-Brochures.html*. Only three levels of groundwater are found in this study area : <15 mbgl (meters below ground level), 15-20 mbgl and > 20 mbgl. After digitizing the groundwater data, it is saved in shape file and later converted into raster dataset. Next, the factor of Distance from City is also saved in shape file by generating multi buffers around Ludhiana city. Five buffer zones are created around the Ludhiana city: 0-2 km, 2-4 km, 4-6 km, 6-8 km and 8-10 km. These distances are measured from the outer limit of city. This data is also converted into raster dataset. Next factor of Distance from Canals is drawn by generating multi buffers around canals. Five buffer zones are drawn: 0-250 mt, 250-500 mt, 500-750 mt, 750-1000 mt and more than 1000 mt from canals. Shape file of this feature is also converted into raster dataset. Similarly, five multi buffers are generated around the drains i.e. 0-250 mt, 250-500 mt, 500-750 mt, 750-1000 mt and more than 1000 mt from drains. Likewise, this shape file is also converted into raster dataset. Next factor of Distance from Settlements / villages is drawn by generating two buffer zones : 0-500 mt and more than 500 mt from settlements/villages. Then this shape file is also converted into raster dataset. Next factor of slope is obtained by downloading DEM from Bhuvan official website https://bhuvan.nrsc.gov.in/bhuvan_links.php. This data is already in raster format so it does not require conversion. However it is redrawn by reclassifying the slope categories i.e. 0-10 degrees, 10-20 degrees, 20-30 degrees, 30-40 degrees and more than 40 degrees. Lastly the factor of Distance from Roads is drawn by generating multi buffers around roads. Five buffer zones are created around roads : 0-100 mt, 100-200 mt, 200-300 mt, 300-400 mt and more than 400 mt. This data is also saved in shape file and later converted into raster dataset.

VI. ASSIGNING INFLUENCE AND WEIGHTS

Once all data is converted into raster datasets, it is all set to assign influence to each factor and weights to the subclasses of each factor. This is done because all factors are not equally important. Influence of each factor varies and similarly subclasses of each factor also affect differently. The influence is assigned in percentage to each factor i.e. the most important factor is assigned the maximum percentage of influence and this percentage of influence decreases with the decreasing importance of each factor. Then subclasses of each factor are assigned weights on the scale value of 0-5. Assigning percentage of influence to all factors and weights to subclasses of each factor is the most crucial stage in site identification for solid waste management. Table 1 depicts both the percentage of influence to all factors and weights to subclasses of each factor. Influence and weights are assigned on the basis of local geography, perusing similar studies and by consulting academicians, scientists, planners and administrators.

VII. Discussion on Factors

(1) Landuse landcover:

In the study area four prominent features of landuse landcover appear on the satellite imagery. These are cultivated land, settlements, plantations/forest and industry. Besides this, roads and some water bodies also appear like river, drains and canals which are being considered separately. However, River Sutlej covers 10 sq km of study area, canals cover 2.47 sq km and drains cover 1.67 sq km of study area. Roads cover 18 sq km of study area and are being considered separately. Fallow land is almost absent and being categorized in the cultivated area wherever it appears. Among four prominent features the industries which are 244 in number cover only 4 sq km of study area; Plantations numbering 558 cover 28 sq km of study area; settlements numbering 277 cover 53 sq km and cultivated land covers the 748 sq km of study area and is highest among all categories of landuse landcover. Areas for solid waste management will be avoided in the settlements, forests/plantations and industry (fig:3).

(2) Soil Drainage:

Soil drainage refers to the movement of water within the pore spaces of soil. This factor is included keeping in mind the leaching that may take place in the solid waste management site. As per the soil map of Punjab prepared and revised by National Bureau of Soil Survey & Landuse Planning and Punjab Remote Sensing Centre, Ludhiana the soils of Punjab have been categorized in seven categories on the basis of soil drainage. These categories are described in the given table. In the present study area only three categories are found: i.e. D4, D5 and D7. Areas falling under D4 category are found in the western and northern part of study area covering an area of 99 sq km. D5 category covers the maximum part (596 sq km) of the study area. D7 category areas are found along the river Sutlej in the northern part covering only 171 sq km. Site for solid waste management will be avoided in the excessively drained soil because of expected leaching during rainy season. Leachates of solid waste can pollute soil as well as groundwater (fig:4).

S. no.	Soil Drainage Code	Soil Drainage Category
1	D1	Very Poorly Drained
2	D2	Poorly Drained
3	D3	Imperfectly Drained
4	D4	Moderately Well Drained
5	D5	Well Drained
6	D6	Somewhat Excessively Drained
7	D7	Excessively Drained

Table 2: Types of soil in Punjab on the basis of soil drainage

Figure 1: Location of Punjab State in India

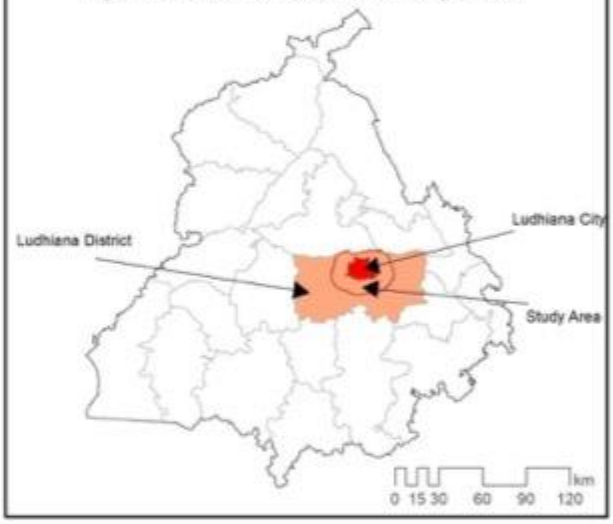


Figure 2: Location of Study Area in Punjab State

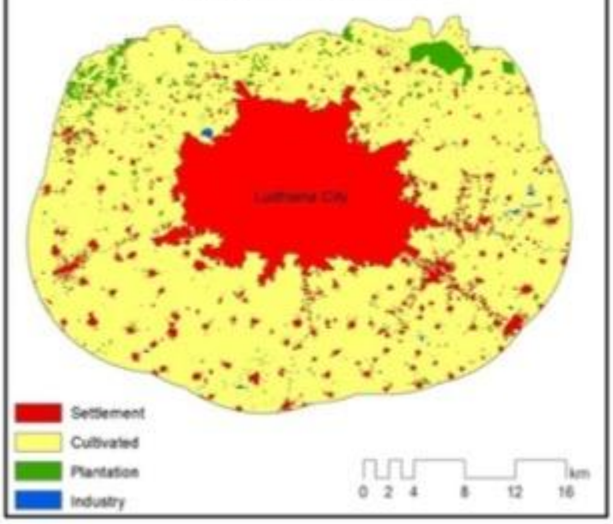


Figure 3: Landuse Landcover

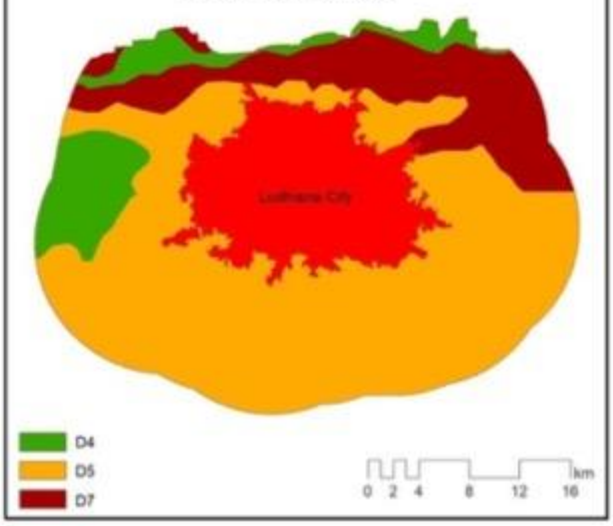


Figure 4: Soil Drainage

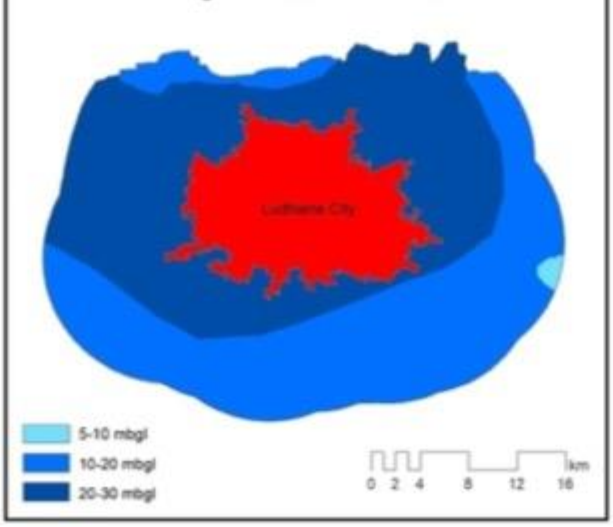


Figure 5: Groundwater Level

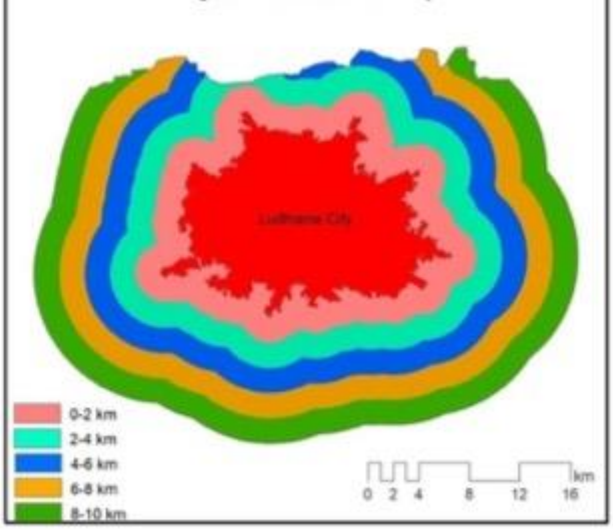


Figure 6: Distance from City

(3) Groundwater Level:

This factor is included because of chances of its getting polluted from the leachate. Groundwater level is expressed here as mbgl or meters below ground level. As per the district maps of groundwater level prepared by Central Groundwater Board, three levels are found in this study area. These are 5-10 mbgl, 10-20 mbgl and 20-30 mbgl. Area with groundwater level of 5-10 mbgl is very limited i.e. only 4 sq km and is located in the eastern boundary of the present study area. There are two areas where groundwater is 10-20 mbgl. One is located in the northern part along river Sutlej and another makes a wide arc along the eastern and southern boundary of study area. The northern area is of 28 sq km and the second area of arc shape is of 374 sq km. Together both areas make 402 sq km where groundwater is 10-20 mbgl. Area where groundwater level is 20-30 mbgl is of 459 sq km and is found in the interior and western parts of study area. Site for solid waste management is preferred where groundwater is deep enough so that leachate from solid waste cannot pollute the resource of groundwater (fig:5).

(4) Distance from City:

Factor of Distance from city plays an important role in identification of areas for solid waste management because cities grow rapidly. Past experience of Jainpur and Jamalpur sites of Ludhiana shows that these were identified several years back and were outside the city. But now both especially Jamalpur has become part of the city due to urban growth. Any site for solid

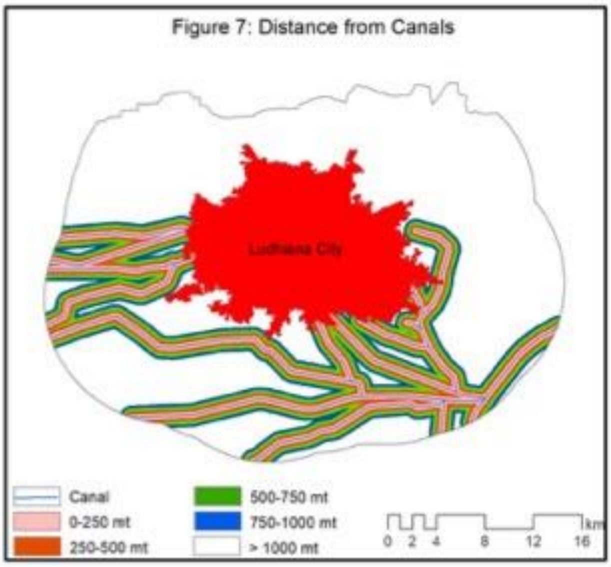


Figure 7: Distance from Canals

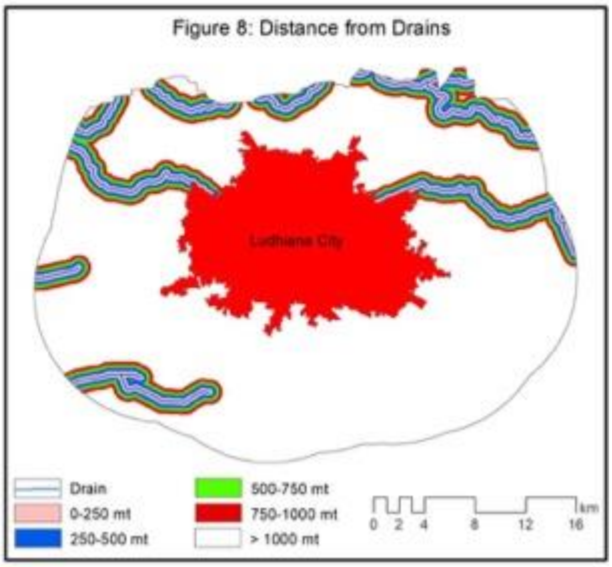


Figure 8: Distance from Drains

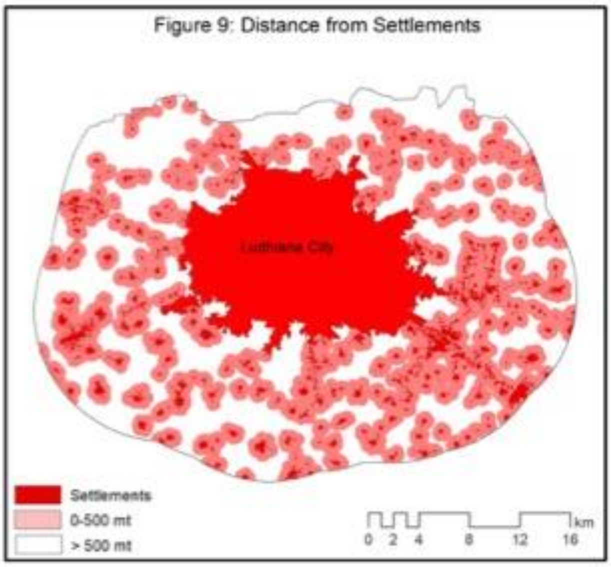


Figure 9: Distance from Settlements

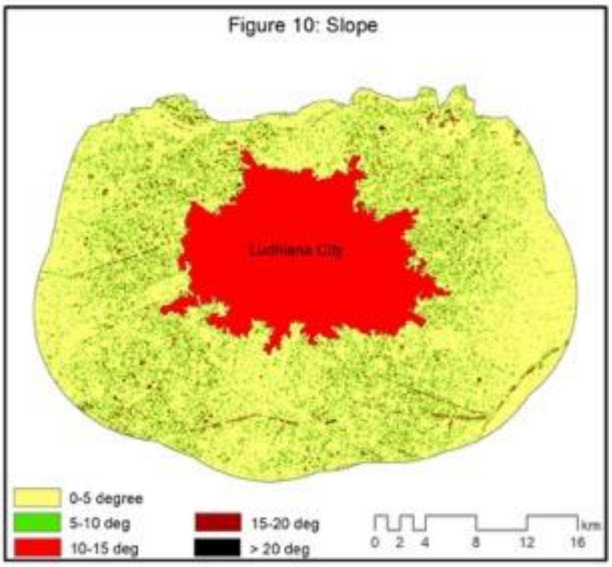


Figure 10: Slope

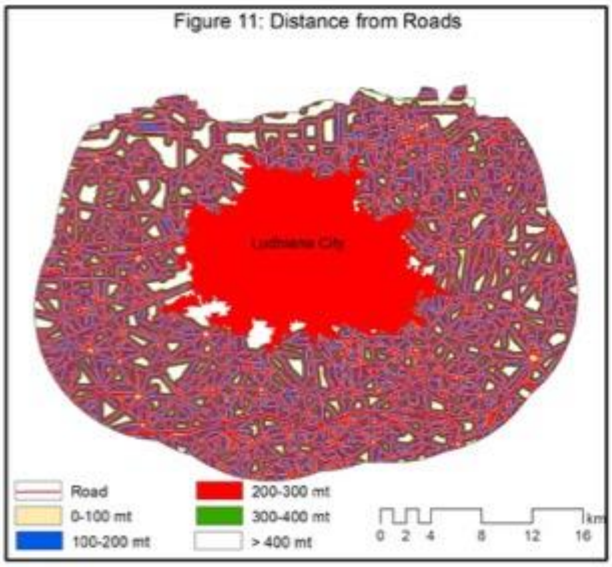


Figure 11: Distance from Roads

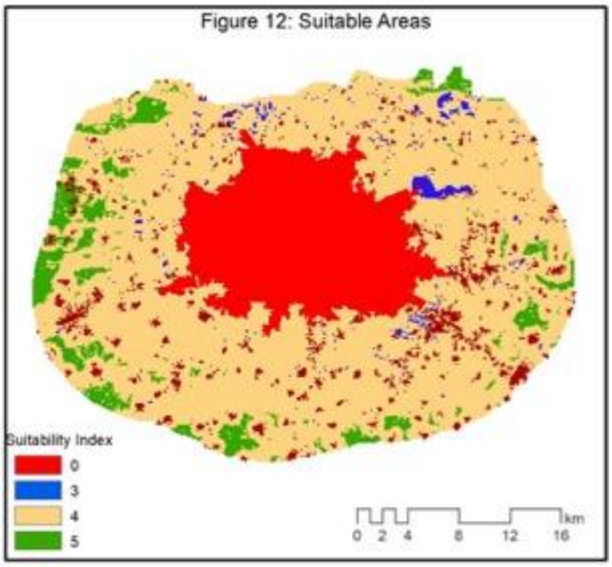


Figure 12: Suitable Areas

waste management generally serves for 30-40 years. Considering the factor or urban growth, efforts can be made to keep such areas out of urban landscape.

In the present case, the study area is divided into five zones on the basis of distance from city. These are 0-2 km, 2-4 km, 4-6 km, 6-8 km and 8-10 km from the outer limit of the city. First zone of 0-2 km lies immediate to the city and covers an area of 184 sq km. Second zone of 2-4 km covers 166 sq km; zone of 4-6 km also covers 166 sq km; 6-8 km zone covers 172 sq km and last zone of 8-10 km covers area of 176 sq km. As per Census of India the decadal growth rate (2001-2011) of Ludhiana city is 33.79%. Considering this growth rate the site for solid waste management can be avoided in the zones that are closer to the city and preferred in the zones that are away from the city (fig: 6).

(5) Distance from Canals:

This factor is included for fear of canals getting polluted from surface runoff emanating from proposed site. Since canals carry fresh water of rivers for irrigation, these need to be protected from pollution. Sirhind canal is the main canal that originates near Ropar and flows through the southeastern part of the study area. Near Doraha this canal gets divided into three branches: Patiala branch, Bathinda branch and Abohar branch. Patiala branch doesn't flow for long distance in this study area. The Bathinda branch flows through the southern parts and Abohar branch flows through the central parts of the study area. In total 14 number of canals flow in this study area including all branches and distributaries which cover 2233997 sq mt of area and run for 368 km. Five buffer zones are made along all the canals i.e. 0-250 mt; 250-500 mt; 500-750 mt; 750-1000 mt and more than 1000 mt. Efforts will be made to keep the solid waste management area away from the canals so that canal water doesn't get polluted from the solid waste (fig: 7).

(6) Distance from Drains:

Most drains are natural channels that help in controlling floods and effort are made to keep these pollution free. A total of 5 number of nullahs or drains flow in this study area besides the major river of Sutlej that flows east to west for about 28 km along the northern boundary of the study area. All the drains of study area flow for 63 km and cover an area of 960876 sq mt. Budha Nullah is famous for its polluted waters because of inflow of domestic and industrial sewage. It flows through almost middle of this area and joins River Sutlej near Wajipur Kalan. Other drains flow for very small distances in this area. Like canals five buffer zones are made along all drains and the river: i.e. 0-250 mt; 250-500 mt; 500-750 mt; 750-1000 mt and more than 1000 mt. efforts are made to keep the solid waste management area away from the river and drains so that the water doesn't get polluted from the solid waste (fig: 8).

(7) Distance from Villages:

There are 277 number of villages / settlements in the study area. These villages occupy an area of 53.15 sq km. It is worth mentioning here that only inhabited part of villages is under consideration. This inhabited part grows at a very nominal rate. As per census of India the decadal (2001-2011) population growth for the rural areas of Ludhiana is just 6.2 % as compared to 17.9 % for the urban areas. Keeping in view this slow growth of rural population only two buffer zones are created around all villages. These are 0-500 mt and more than 500 mt. Purpose of making these two buffers is to avoid areas for solid waste management in the immediate vicinity of the villages so as to keep the environment clean for the inhabited area. People also do not prefer that such site is located in or around their village. Solid waste management rules also do not allow solid waste management within 500 mt radius of a settlement (fig: 9).

(8) Slope:

The study area lies in the plain area. Most parts of it are absolutely flat except few exceptions which lie along the river Sutlej or canals. On the basis of slope the area has been divided into five zones : 0-5 degrees, 5-10, 10-15, 15-20 and more than 20 degrees. Maximum area i.e. 76.77 % lies in the category of 0-5 degrees of slope; followed by 19.51 % in the category of 5-10 degrees of slope; 3.02 % in 10-15 degrees of slope; 0.54 % in the category of 15-20 degrees of slope and 0.13 % in the category of more than 20 degrees of slope. The figures reveal that around 96.28 % of the study area has slope of less than 10 degrees. The map reveals that most of the steep slope areas are only small patches that lie along river Sutlej or are embankments along canal and drains. Looking at the flatness of study area it is expected that chances of heavy runoff is minimum. Flat areas are preferred for solid waste management and are in abundance in this study area (fig: 10).

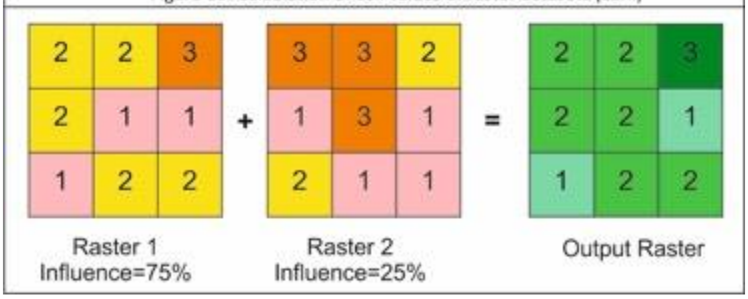
(9) Distance from Roads:

The last factor that can affect the site identification for solid waste management of Ludhiana municipal corporation is roads. In this study area roads are very dense and run for 21215 km and are available in all parts. Most of the roads are village roads and are metalled. Road connectivity is important because everyday solid waste has to be transported to the site. Good road connectivity ensures speedy and efficient disposal of solid waste. Therefore the proposed area in the vicinity of roads is preferred. To locate the suitable areas for solid waste management, five buffer zones are created along all the roads : 0-100 mt, 100-200 mt, 200-300 mt, 300-400 mt and more than 400 mt (fig: 11).

VIII. WEIGHTED OVERLAY ANALYSIS

This is a technical stage in identification of areas for solid waste management. Since all factors are not equally important and influence of each factor varies, it is desirable to find a tool that can consider the varying importance of each factor as well as subclasses of each factor. The tool of Weighted Overlay Analysis takes into account the value assigned to each cell of the raster. Each raster contains tens of thousands of cells with different weights and there are nine raster datasets in this study and all have different percentage of influence. It appears

Figure 13: Calculation of cell values of raster datasets (ESRI)



a very bewildering and difficult task but the tool of Weighted Overlay Analysis makes it explicable by overlaying all the raster datasets and calculating the cell values of each raster.

Major steps in weighted overlay analysis tool:

- The values of input raster are reclassified on a common evaluation scale.
- The cell values of each raster are multiplied by the percentage of influence of each raster.
- The resultant cell values are added together to generate the output raster.

When the tool of Weighted Overlay Analysis is run, the process of calculations begins for all the raster datasets and their cells. The result of this tool is the generation of a new raster dataset that categorizes the study area into several zones on the basis of suitability with suitability index ranging from 0-5 (fig: 12). That means areas that have 5 scale value or suitability index are the most suitable for solid waste management. Areas with lower scale value or suitability index are less suitable for solid waste management. In this study the tool of weighted overlay analysis generates the output raster dataset with four scale value of 0,3,4 and 5. Areas with 5 suitability index are extracted by using the tool of 'Extract by Attributes' which is a spatial analyst tool in Arc Toolbox. This tool again generates a new raster that contains only those areas that have high suitability index of 5. This raster dataset is then converted in a shape file using 'Raster to Polygon' tool and then converted to KML file using 'Layer to KML' tool in Arc Toolbox. This KML file alongwith other KML files of all the nine factors are then viewed in Google Earth. This is a validation step where one can manually corroborate or double check the result of 'Weighted Overlay Analysis'. In this step all layers are viewed above the layer of Google Earth.

CONCLUSION

In the end it may be concluded that all factors have been considered that are capable of affecting the identification process. The assigning of influence and weights to all the factors and their subclasses is based on the views of those who are skilled and also on the basis of studies that have already been done on this topic. The 'Weighted Overlay Analysis' tool has also worked well and brought results as per the inputs. The results of weighted overlay analysis have also been validated by overlaying on layers of all the nine factors in Google Earth which in turn also justifies the assigning of influence and weights to all the factors and their subclasses.

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